POLYCRYSTALLINE DIAMOND MEMS RESONATOR TECHNOLOGY FOR SENSOR APPLICATIONS

Nelson Sepúlveda and Dean M. Aslam

Electrical and Computer Engineering Department, Michigan State University, E. Lansing, MI, USA
sepulve6@msu.edu

D. A. Czaplewski, J. P. Sullivan, T. A. Friedmann

Sandia National Laboratories, Albuquerque, NM, USA

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Abstract

MEMS resonators, currently made out of poly-Si [1], have potential applications in the areas of RFMEMS, resonant sensors and MEMS oscillators. However, due to material limitations of poly-Si resonators, new materials such as polycrystalline diamond (poly-C) offer an excellent alternate [2,3]. The goal of this work is to develop a reliable and reproducible poly-C resonator technology for possible applications in resonant sensors and MEMS oscillators, benefiting from carbon based micro and nano technologies developed at Michigan State University [4]. The poly-C resonators, fabricated at MSU are tested using electrostatic (MSU) and piezoelectric (Sandia National Laboratories) actuation methods.

FABRICATION TECHNOLOGY

Continuous poly-C films with low surface roughness and high quality (indicated by high sp3/sp2 ratios) affect the resonator performance. A better control of nucleation density along with deposition parameters can help produce high quality poly-C films [4]. An earlier study [3] showed the influence of growth temperature and diamond powder size on the poly-C film quality. Higher growth temperatures typically lead to better film quality but rough surface. The seeding was provided by nanodiamond particles (10 - 50 nm) leading to a nucleation density of 1×10^{11} cm^{-2}. The poly-C films, with surface roughness in the range of 18-23 nm, were patterned using dry etching. This work includes the comparison between poly-C films grown in different environments. One set of samples were grown in MPCVD in the temperature range of 600-650 °C using 1.5% CH_4 in hydrogen, and the other were grown in the same temperature range but using a gas mixture of $Ar/H_2/CH_4$ (100:2:1) .

Sidewall Roughness

Another important point is the sidewall roughness resulting from dry etching, which depends on the grain size of the poly-C film. It has been reported that the optimum diamond grain size can be controlled by adjusting the flow rate of Ar/H_2 in the MPCVD reaction chamber [5,6]. Poly-C films were grown in a gas mixture using $Ar/H_2/CH_4$ plasma. The sidewall smoothness of the fabricated resonator structures using the new films are compared to that of earlier results (poly-C films grown in H_2 plasma) as shown in figure 1. The results show a smoother film sidewall for poly-C films grown in $Ar/H_2/CH_4$ plasma. These results are reported for the first time.

TESTING

The previous studies of poly-C resonator technology [3] with minimum feature sizes in the range of 1 - 2 μm led to an excellent quality of released structures. These structures have now been excited using electrostatic actuation and the initial results are shown in figure 2. Bridges and comb-drive structures have been tested. The frequencies and quality factors are in the range of 0.303 – 2.09 MHz and 1,000 - 1,500, respectively. Currently, the samples are being measured at Sandia National Laboratories using piezoelectric actuation. The results from these measurements will be compared with the results obtained by using electrostatic actuation.

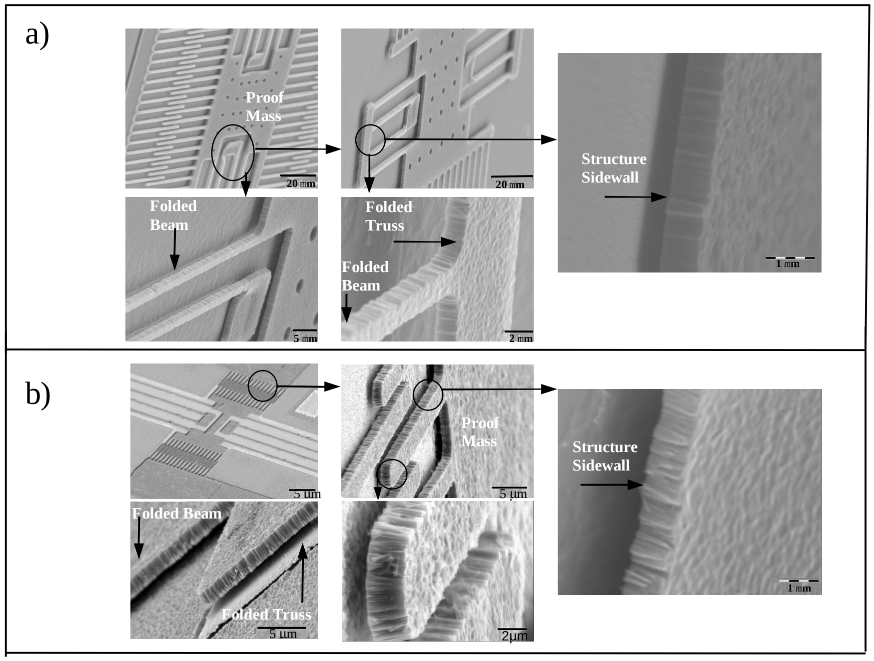

Figure 1 Poly-C structures grown in different environments (a)Ar H_2/CH_4, (b) H_2/CH_4

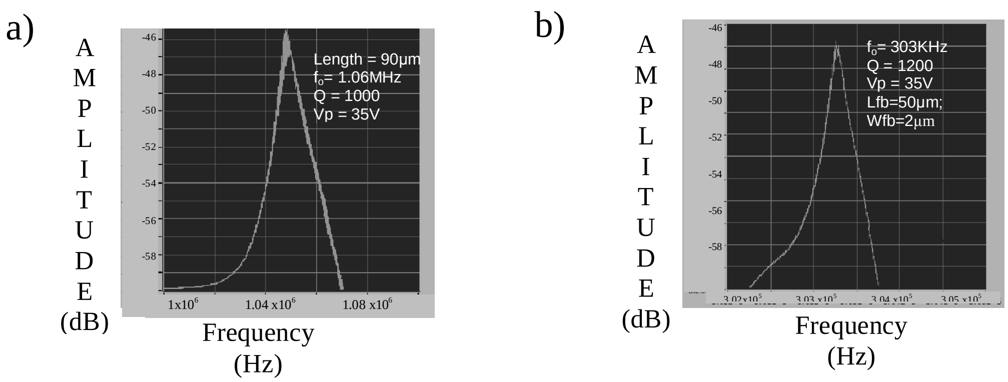

Figure 2 Testing results for a poly-C bridge (a), and a comb-drive resonator (b).

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